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RELATING ACOUSTIC BACKSCATTER DATA TO THE GEOMORPHOLOGY OF THE MID-ATLANTIC RIDGE

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ABSTRACT

In this work an attempt is made to invert backscatter data collected on the Acoustic Reverberation Special Research Project (ARSRP) Reconnaissance Cruise to extract fine- and micro-scale geomorphology of a site on the western flank the Mid-Atlantic Ridge. To achieve this goal a methodology was developed and tested using two numerical models of different fidelity and computational load. Both models are based on the Helmholtz-Kirchhoff (H/K) theory for near-normal incidence. The inversion method was then applied to the ARSRP reconn data to extract the Mid-Atlantic Ridge geomorphology. Preliminary results and problems with using the ARSRP reconn data for this analysis are discussed. A proposal to modify the measurement methodology for some of the planned data collection in the upcoming ARSRP experiment is made.

INTRODUCTION

The purpose of this work is to establish and test a relationship between backscatter measured at high grazing angles during the Acoustic Reverberation Special Research Program (ARSRP) Reconnaissance Cruise and the fine-scale geomorphology of the area of the western flank of the Mid-Atlantic Ridge and to develop a means of extracting estimates of the geomorphology from scattering data. The work originated in an effort to use backscatter data taken in conjunction with bathymetric surveys using swath bathymetry systems [1-3]. The low-frequency active acoustic experimental system aboard the R/V Cory Chouest can collect backscatter data with characteristics similar to swath bathymetry system backscatter data, only at much lower frequencies.

The purpose of the ARSRP experiment being to address questions of low grazing-angle scatter, fully calibrated data at high grazing were not taken. This work, therefore, uses an estimated off-axis beam level in lieu of an actual calibrated level. Clearly, this is not the desirable situation, but the object here is to develop and demonstrate the method and provide a convincing argument for measurements from the Cory in the future that support this important application.

(δ), but does not account for the effects of diffraction from the microroughness (rms heights σ) on the facet. Except for the theoretical work of McDaniel [8] and the implementation into a practical algorithm (the Bistatic Scattering Strength Model, BISSM) by Caruthers and Novarini [ref. 9, Eq. 4], composite roughness theory assumes that microroughness affects non-specular diffuse scatter only. Heuristically, the BISSM algorithm includes the "Eckart factor" [10] as a multiplier on the standard formula for facet scatter. The Eckart factor is a measure of coherence loss in the specular direction due to scattering from microroughness on the facets. It is given by e^{-g}, where $g = 4k^2\sigma^2$, k is the acoustic wavenumber. A more theoretical basis for this form of rough facet scatter can be obtained with additional approximations made on McDaniel's Eq. 16 of ref. 7. Therefore, we give the form of the backscatter scattering strength for facet scatter in the BISSM algorithm to be:

$$BS = \frac{e^{-g}}{8\pi\delta^2\cos^4\Theta}\exp[-\tan^2\Theta/(2\delta^2)]$$

It should be noted that backscattering strength contains information about microroughness and rms slopes.

The intermediate limit between fine-scale and micro-scale is subject to the analysis done in this work. The estimated geomorphology of the reconn area was used to simulate surfaces with known geomorphology and the H/K model was used to simulate scattering. BISSM was applied to invert the simulated data to recover the geomorphology and develop the methodology for determining the partition between fine- and micro-scales. The model requires the rms slope of the fine-scale surface (the footprint) and rms heights of the microroughness. Both rms heights and slopes are band limited quantities. (Large-scale is treated as deterministic and excluded from this analysis.) The lower limit on wavenumber for slopes is controlled by the footprint size and the upper limit on wavenumber heights is controlled by sampling.

VALIDATION

Before we actually apply this simple model to the inversion of the ARSRP data, we will analyze its validity and address an issue concerning the location of the scale partition between facet and diffuse scatter. For this we will use a more fundamental scattering approach called Helmholtz-Kirchhoff theory (H/K). The reader is referred to ref. [11] for details of this H/K model and to ref. [3] for additional discussion related to validating this approach. The following deals with some specifics of interest here: First, the scattered intensity is obtained as the ensemble average of pp* over an ensemble of surfaces used in the H/K modeling, where p is the complex scattered pressure at a point. The receiving point is selected to coincide with the source point

the scattering calculations.

Figures 2, 3, and 4 show the frequency dependencies of scattering for surfaces 01, 0D, and 0E, respectively. For ARSRP applications a frequency of 250 Hz is relevant, but we computed the other frequencies also to aid in analysis and validation. Figures 5a and 5b show the comparison between the H/K benchmark modeling and the application of BISSM for the 0D family of surfaces. Note the similarity of the curves is very good; however, the rms slopes required to fit the data is lower for the BISSM curves than the rms slopes of the simulated surfaces. While not too bad, this is an anomalous case and generally the fit was better. In particular, the application to the simulated surface at ARSRP Site A is especially good (Fig. 6).

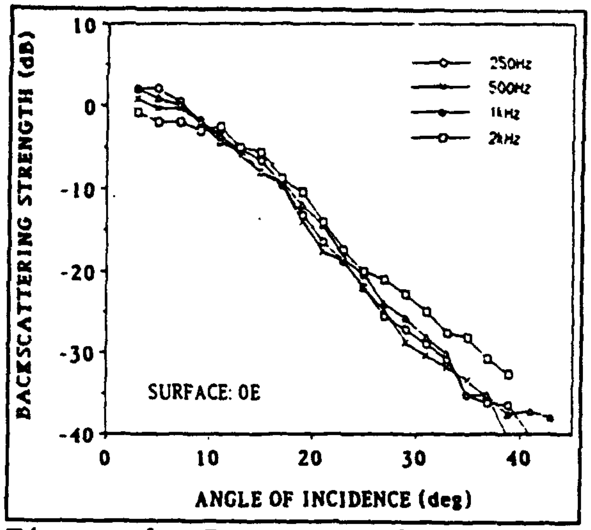

Figure 4: Frequency dependence of scattering from surface 0E.

Using the results at Site A (surface 01), surface 0E, some of the smoother surfaces of the 0D family (0I,0J,0D,0K,0L, & 0M), and a few others we have arrived at a tentative criterium for setting this scale partition. According to our findings a partition of scales occurs where the quantity g (microroughness parameter) is approximately unity. That is, the low-wavenumber limit band for rms heights (σ) is such that $4k^2\sigma^2=1$; at 250 Hz this equates to a value of 0.47 m for the rms heights and typically the partition scale is at one to several wavelengths. Table I gives some of the values of σ and δ that result from the fitting. The above criterium appears to break down for very rough surfaces.

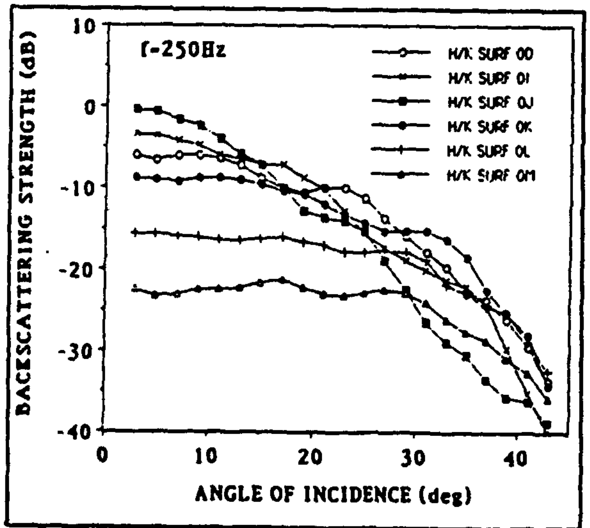

Figure 5a: H/K scattering for 0D family of surfaces.

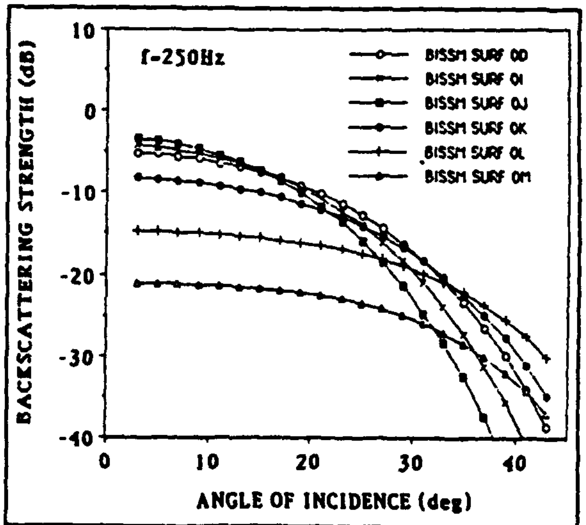

Figure 5b: BISSM scattering for 0D family of surfaces.

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